JACC Vol. 21, No. 7
June 1993:1550–6

CLINICAL STUDIES

Excimer Laser–Assisted Coronary Angioplasty for Lesions Containing Thrombus

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Objectives. **The purpose of this study was to analyze the success rates for excimer laser–assisted coronary angioplasty performed in patients undergoing angioplasty for lesions containing thrombus.**

Background. **The presence of intracoronary thrombus increases the risk of a poor clinical outcome after balloon angioplasty. The effect of intracoronary thrombus on the safety and efficacy of excimer laser–assisted coronary angioplasty is unknown.**

Methods. **Percutaneous excimer laser–assisted coronary angioplasty was attempted in 142 patients, of whom 12 had angiographic evidence of intracoronary thrombus in 14 lesions, defined as a filling defect surrounded by contrast medium or an area of contrast staining.**

Results. **Clinical success (<50% residual stenosis without myocardial infarction, death or bypass surgery at any time during hospitalization) was achieved in 7 (58%) of the 12 patients with intracoronary thrombus, compared with 123 (95%) of the 130 patients without thrombus ($p = 0.00001$). Angiographic and clinical complications were more common in patients with thrombus: embolization (25% vs. 1%, $p < 0.001$), myocardial infarction (33% vs. 2%, $p < 0.001$), abrupt closure (17% vs. 4%, $p = 0.049$). Angiographic restenosis at 6 months was seen at 7 (70%) of 10 treated sites with intracoronary thrombus and at 59 (51%) of 116 sites without thrombus ($p = 0.245$).**

Presence of intracoronary thrombus was identified as the most important predictor of clinical success ($p = 0.013$) by multivariable logistic regression analysis, which controlled for other covariables, such as lesion complexity or lesion location in a saphenous vein graft.

Conclusions. **This analysis shows that the success of excimer laser–assisted coronary angioplasty is compromised when thrombus is detected angiographically. Further investigation of other strategies is needed to improve the outcome of angioplasty for this challenging problem.**

(J Am Coll Cardiol 1993;21:1550–6)

Coronary lesions containing thrombus increase the risk of a poor clinical outcome after balloon angioplasty. The likelihood of abrupt closure during balloon angioplasty increases by twofold to ninefold when intracoronary thrombus is detected by angiography in a lesion targeted for angioplasty (1–6).

New pharmacologic and mechanical methods have been investigated to reduce the procedural risk of angioplasty when intracoronary thrombus is present, but none has emerged as a uniformly successful approach to this frequently encountered problem. Although there have been several reports of the experience of excimer laser–assisted coronary angioplasty (7–9), all have excluded patients with angiographic evidence of intracoronary thrombus.

The purpose of this study was to analyze the success rates for excimer laser–assisted coronary angioplasty performed in patients undergoing angioplasty for lesions containing thrombus.

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Manuscript received August 17, 1992; revised manuscript received October 14, 1992, accepted October 28, 1992.

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Methods

Study patients. Between October 26, 1989 and December 31, 1991, coronary balloon angioplasty was performed in 1,180 patients at the Brigham and Women's Hospital in Boston. During the same time period, excimer laser–assisted coronary angioplasty was recommended for the subgroup of 142 patients (12%) if they were judged to be surgical candidates, had an ejection fraction >0.30 and had lesions thought to be approachable with the laser catheters. Patients with intracoronary thrombus were excluded from excimer laser treatment in the cohort of the first 100 patients reported on earlier (7), but they were actively recruited as part of this study to evaluate the safety and efficacy of excimer laser angioplasty for this indication. All patients undergoing excimer laser angioplasty gave informed consent to participate in the protocol approved by the Food and Drug Administration and the Institutional Review Board of the Brigham and Women's Hospital.

Definitions. *Thrombus* was defined as the presence of a globular or elongated filling defect surrounded by contrast

0735-1097/93/$6.00

medium and usually located immediately downstream from a stenosis, or an area of contrast staining noted within the stenosis scheduled to be dilated (10). Clinical success was defined according to the National Heart, Lung, and Blood Institute criteria as a reduction by ≥20% of the narrowing of the vessel diameter, <50% residual stenosis after laser treatment with or without adjunctive balloon angioplasty and the absence of a major complication (death, Q wave or non-Q wave myocardial infarction or need for emergency coronary artery bypass surgery) at any time during the hospital stay (11). *Abrupt closure* was defined by total or subtotal occlusion of the vessel after attempted angioplasty with corresponding Thrombolysis in Myocardial Infarction Trial grade 0 to 1 flow (12) with or without associated symptoms or signs of ischemia, within 24 h of angioplasty. Multivessel disease was denoted by two or more myocardial territories (anterior, lateral, inferoposterior) supplied by stenoses ≥50% (13). Myocardial infarction was defined by the presence of at least two of the three following criteria: 1) prolonged angina (>30 min); 2) total creatine kinase (CK) elevation to >200 mIU/ml (confirmed by CK-MB fraction isoenzyme elevation to ≥2.0% of total CK activity), and 3) electrocardiographic evidence of infarction. Lesion complexity was graded as A, B1, B2 or C according to the American College of Cardiology–American Heart Association Task Force definitions (14), as modified by Ellis et al. (15). Angiographic restenosis was defined by >50% stenosis at the treated site at any time during follow-up. All patients with a successful and uncomplicated dilation were asked to return for follow-up angiography 6 months after the procedure. If patients had follow-up angiography performed >3 months after angioplasty and showed no angiographic evidence of restenosis at that time, they were considered to be free of restenosis because 90% of restenosis occurs within 3 months after angioplasty (16).

Excimer laser coronary angioplasty. Percutaneous excimer laser-assisted coronary angioplasty was performed with the CVX-300 system (Spectranetics Corporation), as previously described (7).

Angiographic analysis. Stenosis severity was determined before angioplasty, after laser treatment with or without adjunctive balloon angioplasty and at follow-up with the use of digital calipers (Mitutoya) by an experienced angiographer unaware of clinical outcome.

Statistical analysis. To determine baseline differences between the groups with and without thrombus, chi-square analysis was used for categoric variables and *t* test for continuous variables. Logistic regression analysis was used to identify predictors of clinical success from a series of clinical (age, gender, diabetes, Canadian Cardiovascular Society classification) and angiographic (thrombus, lesion complexity, length of lesion) variables (17). Odds ratios were provided to estimate the probability that patients with a given variable had increased likelihood of clinical success compared with all other patients without the variable (17). Of the variables evaluated, those found to have borderline significance on univariable analysis ($p < 0.10$) were included in the multivariable analysis. All analyses were performed with standard statistical software (SYSTAT 5.1; LOGIT 2.0). All data are presented as mean value ± SD.

Table 1. Clinical Characteristics of 142 Patients

	No Thrombus (n = 130)	Thrombus (n = 12)	p Value
Age (yr)	59 ± 11	63 ± 7	0.067
Male	95 (73)	10 (83)	0.370
Previous CABG	30 (23)	8 (67)	0.001
Previous PTCA	58 (45)	2 (17)	0.060
Multivessel disease	71 (55)	9 (75)	0.067
Previous MI	44 (34)	7 (58)	0.225
Angina class*			
I	17 (13)	3 (25)	
II	30 (23)	2 (17)	
III	42 (32)	2 (17)	
IV	41 (32)	5 (42)	
Rest angina	41 (32)	5 (42)	0.472

*Canadian Cardiovascular Society classification. Data are expressed as mean value ± SD or number (%) of patients. CABG = coronary artery bypass surgery; MI = myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty.

Results

Patients (Table 1). Excimer laser-assisted coronary angioplasty was attempted in 142 consecutive patients, of whom 12 had angiographic evidence of intracoronary thrombus. The mean age was 63 years for those with and 59 years for those without thrombus ($p = 0.067$). No differences in gender, tobacco use, diabetes mellitus or history of previous myocardial infarction were seen between the two groups. Previous bypass surgery had been performed almost three times more often in patients with thrombus than in those without this angiographic finding ($p = 0.0011$), reflecting the high incidence of thrombus-containing lesions in saphenous vein grafts.

Lesions (Table 2). The 142 patients had a total of 155 stenoses treated with excimer laser coronary angioplasty. Patients with thrombus showed a trend toward increased likelihood of multivessel disease compared with patients without thrombus ($p = 0.067$). Most patients with thrombus had complex lesions, according to the American College of Cardiology–American Heart Association classification of lesion severity (14). No difference in stenosis severity was found between the two patient groups.

No difference was found in lesion eccentricity between thrombus-containing lesions and thrombus-free lesions ($p = 0.365$). Total occlusions were considered to contain thrombus only when evidence of contrast retention was seen. Total occlusions comprised 29% of the lesions with thrombus versus 9% of the lesions without thrombus ($p = 0.153$).

Adjunctive balloon angioplasty was performed in 93% of the lesions of patients with thrombus and in 86% of the lesions in patients without thrombus ($p = 0.533$).

Table 2. Characteristics of 155 Treated Lesions

	No Thrombus (n = 141)	Thrombus (n = 14)	p Value
Vessel location			0.008
SVG	19 (13)	9 (64)	
LAD	77 (55)	2 (14)	
RCA	34 (24)	2 (14)	
LCx	11 (8)	1 (7)	
Lesion type*			0.0002
A	17 (12)	0 (0)	
B1	51 (36)	1 (7)	
B2	28 (20)	0 (0)	
C	45 (32)	13 (93)	
Length (mm)	10.3 ± 6.7	13.1 ± 7.4	0.127
Ostial	20 (14)	1 (7)	0.461
Eccentricity	51 (36)	6 (43)	0.365
Calcified	14 (10)	0 (0)	0.301
Total occlusion	13 (9)	4 (29)	0.153
Bifurcation	4 (3)	0 (0)	0.751
Adjunctive balloon angioplasty	121 (86)	13 (93)	0.533
Stenosis severity (%)	87 ± 15	88 ± 8	0.678
Fluence (mJ/mm)	52 ± 6	48 ± 8	0.122
Repetition rate (Hz)	25 ± 1	25†	1.000
Laser time (s)	21 ± 17	22 ± 18	0.827

*American College of Cardiology–American Heart Association classification as modified by Ellis et al. (15). †No variance exists because all cases were performed at 25 Hz. Unless otherwise indicated, data are expressed as mean value ± SD or number (%) of lesions. LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; RCA = right coronary artery; SVG = saphenous vein graft.

Clinical success (Table 3). Coronary thrombus decreased the likelihood of clinical success. Clinical success was achieved in 7 (58%) of 12 patients with intracoronary thrombus versus 123 (95%) of 130 patients without intracoronary thrombus ($p = 0.00001$). The severity of the stenosis improved from 88 ± 8% to 35 ± 29% in patients with intracoronary thrombus compared with an improvement of 87 ± 15% to 27 ± 16% in patients without thrombus ($p = 0.314$).

Complications (Tables 4 and 5). Angiographic and clinical complications were more common in patients with intracoronary thrombus. Angiographic evidence of embolization appeared in 3 (25%) of 12 patients with thrombus and in 1 (1%) of 130 patients without thrombus ($p < 0.001$). Embolization occurred in one patient with thrombus during passage of the laser catheter alone and in two such patients during adjunctive balloon angioplasty after successful laser angioplasty. Embolization was often associated with the angiographic problem of side branch loss or "no reflow" (Fig. 1) and was treated with intracoronary urokinase in doses of

Table 3. Clinical Success and Angiographic Results in 142 Patients

	No Thrombus (n = 130)	Thrombus (n = 12)	p Value
Clinical success	123 (95%)	7 (58%)	0.00001
Postprocedural stenosis	27 ± 16%	35 ± 29%	0.314

Table 4. Complications in 142 Patients

	No Thrombus (n = 130)	Thrombus (n = 12)	p Value
Embolization	1 (1)	3 (25)	< 0.001
MI	2 (2)	4 (33)	< 0.001
Abrupt closure	5 (4)	2 (17)	0.049
Spasm	1 (1)	0 (0)	0.760
Emergency CABG	2 (2)	0 (0)	0.665
Major dissection	6 (5)	0 (0)	0.446
Minor dissection	10 (8)	1 (8)	0.936
Perforation	3 (2)	0 (0)	0.598

Data are expressed as number (%) of patients. Abbreviations as in Table 1.

250,000 to 1 million U in all cases, leading to partial improvement in flow after 15 to 30 min. Despite this, myocardial infarction was documented in each case of embolization. The overall incidence of myocardial infarction was higher in patients with thrombus (33%) than in patients without thrombus 2% ($p < 0.001$). Emergency bypass surgery was performed in 0 of 12 patients with intracoronary thrombus (0%) and in 2 of 130 without thrombus (2%, $p = 0.665$). After emergency consultation with a cardiac surgeon, no patient with intracoronary thrombus and embolization underwent emergency bypass surgery because of the concern of poor distal runoff. There were more filling defects after the procedure in patients with thrombus (17%) than in patients without thrombus (1%, $p = 0.0002$). Abrupt closure was more common in patients with thrombus (17%) than in patients without thrombus (4%; $p = 0.049$). Although most cases of embolization occurred in saphenous vein grafts, this location was also the site of successful laser thrombolysis in two cases (Fig. 2).

Predictors of clinical success (Table 6). Logistic regression analysis was used to identify predictors of clinical success. Variables such as lesion complexity, as graded by the American College of Cardiology–American Heart Association classification (14), saphenous vein graft stenosis and presence of intracoronary thrombus were associated with reduced likelihood of clinical success on univariable analysis; however, multivariable analysis controlled for possible confounding covariables and identified the presence of intracoronary thrombus ($p = 0.013$) as the most important factor affecting clinical success in this group of patients. In the multivariable model, saphenous vein graft lesions as a group were no longer associated with decreased success. Instead, angiographic evidence of intracoronary thrombus was identified as an independent predictor of unsuccessful excimer laser angioplasty.

Restenosis. Follow-up angiography at a mean of 5.4 ± 2.2 months was available for 126 (81%) of 155 lesions. Angiographic restenosis, defined as >50% stenosis on quantitative angiography by an experienced angiographer unaware of the clinical outcome, was seen in 7 (70%) of 10 lesions with intracoronary thrombus and in 59 (51%) of 116 lesions without thrombus.

Table 5. Patients With Thrombus: Procedural Outcome

Pt No.	Age (yr)/ Gender	Vessel	Stenosis (%) Pre	Stenosis (%) Post	Adjunctive PTCA	Emb	MI	AVC	CABG	Other Treatment	Clinical Success	Stenosis (%) Follow-Up
1	69/M	LAD	89	36	Yes	No	No	No	No	—	Yes	74
2	61/M	SVG	84	23	Yes	No	No	No	No	—	Yes	47
3	63/M	RCA	76	30	Yes	No	No	Yes	No	—	Yes	31
4	60/F	RCA	100	100	Yes	No	No	No	No	—	No	100
5	50/M	SVG	89	19	Yes	No	No	No	No	—	Yes	85
		SVG	80	21	Yes	No	No	No	No	—	Yes	51
		LCx	100	42	Yes	No	No	No	No	—	Yes	79
6	72/M	SVG	91	20	Yes	No	No	No	No	—	Yes	—
7	68/M	SVG	88	28	Yes	No	No	No	No	—	Yes	100
8	73/F	SVG	82	0	No	No	Yes	No	No	—	No	2
9	65/M	SVG	80	39	Yes	Yes	Yes	No	No	Urokinase	No	100
10	67/M	LAD	85	31	Yes	No	No	No	No	—	Yes	—
11	54/M	SVG	81	15	Yes	Yes	Yes	No	No	Urokinase	No	—
12	59/M	SVG	100	100	Yes	Yes	Yes	Yes	No	Urokinase +IABP	No	—

AVC = abrupt vessel closure; Emb = embolization; F = female; IABP = intraaortic balloon pump; M = male; Post = after laser-assisted angioplasty; Pre = before laser-assisted angioplasty; Pt = patient; UK = urokinase; other abbreviations as in Tables 1 and 2.

Discussion

In this study, the presence of intracoronary thrombus increased the risk of a poor clinical outcome after excimer laser coronary angioplasty. The overall clinical success rate was 58% when thrombus was present and 95% when it was absent. The presence of intracoronary thrombus increased the incidence of distal vessel embolization, abrupt vessel closure and myocardial infarction. Multivariable regression analysis showed that the presence of thrombus is associated with decreased success after controlling for other variables, such as lesion complexity and lesion location.

In our study three patients had distal embolization and no flow. This is a complication that has few effective treatment options if intracoronary thrombolysis fails to restore flow. Myocardial infarction almost invariably occurs. Emergency bypass surgery is not effective if distal runoff is not present.

Treatment of intracoronary thrombus. A common problem, intracoronary thrombus has been strongly associated with an increased risk for acute coronary occlusion and decreased clinical success (1–6). The hazard of angioplasty in this setting is probably related to the principle that "thrombus begets thrombus," particularly after mechanical disruption by a balloon catheter.

Investigators have tried several adjunctive therapies, focusing mainly on the suppression of platelet aggregation and thrombus formation. Barnathan et al. (18) retrospectively found that the incidence of occlusive coronary thrombi detected by angiography 30 min after balloon dila-

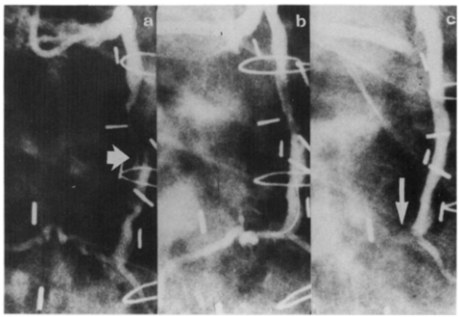

Figure 1. Failed laser ablation. A 65-year old man developed angina 9 years after coronary bypass surgery associated with a complex lesion and filling defects (**arrow**) in the midportion of the graft supplying an obtuse marginal branch (**a**). After laser-assisted coronary angioplasty (**b**), the lesion was slightly improved, but adjunctive balloon angioplasty (**c**) resulted in embolization and loss of flow to the proximal marginal branch (**arrow**) despite the use of urokinase.

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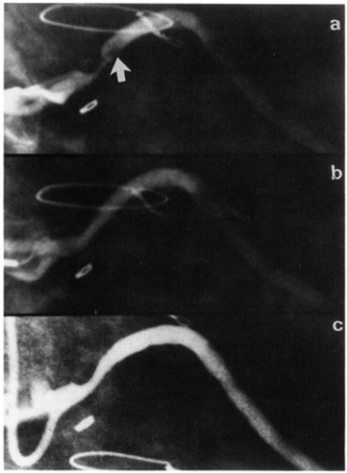

Figure 2. Successful laser ablation. A 61-year old man developed angina 12 years after coronary bypass surgery associated with a complex stenosis and filling defect (**arrow**) in the graft supplying the left anterior descending coronary artery (**a**). After successful laser and balloon angioplasty, the residual stenosis was reduced to 23% (**b**) and remained improved at follow-up angiography (**c**).

tion was significantly lower in patients treated with aspirin (1.8% vs. 10.7%).

Retrospective analysis suggests that the incidence of angioplasty-associated complications may diminish with heparin and aspirin treatment for unstable angina or intracoronary thrombus. Laskey et al. (19) reported that heparin infusion before angioplasty for a mean of 6 days in patients with intracoronary thrombus was associated with a significantly lower incidence of coronary occlusion than that among patients who did not receive heparin (6% vs. 33%).

Adjunctive intracoronary thrombolysis has been tried as an adjunct with balloon angioplasty. Resolution of large coronary thrombi has been reported with intracoronary streptokinase or intravenous tissue-type plasminogen activator or with large (up to 1.5 million U) bolus doses of intracoronary urokinase, followed by successful coronary angioplasty (20).

Intracoronary urokinase. Goudreau et al. (21) reported clinical success in 39 (78%) of 50 patients who received intracoronary urokinase as an adjunct to balloon angioplasty in patients with stenoses complicated by the presence of intracoronary thrombus. Hartmann et al. (22) reported short-term success in 37 (79%) of 47 occluded bypass grafts treated with adjunctive urokinase (22). Suryapranata et al. (23) used intracoronary streptokinase in 12 patients who experienced abrupt vessel closure during balloon angioplasty for unstable angina, but myocardial infarction occurred in 50% of the patients. Schieman et al. (24) used intracoronary urokinase as adjunctive treatment for flow-limiting thrombus formation during coronary angioplasty in patients with acute ischemic syndromes. Intracoronary urokinase (mean dose 141,000 U over approximately 30 min, range 100,000 to 250,000) was used in 10 patients with unstable angina who developed imminent vessel closure during angioplasty. Urokinase therapy and repeat balloon angioplasty were successful in restoring flow and relieving ischemia in 9 of 10 patients. No patient had acute myocardial infarction, needed bypass surgery or had clinical or angiographic evidence of reocclusion.

Table 6. Logistic Regression Analysis for Predictors of Clinical Success

	Univariable		Multivariable	
	Odds Ratio (95% CI)	p Value	Odds Ratio (95% CI)	p Value
Clinical variables				
Age (per additional yr)	0.98 (0.93, 1.04)	0.548		
Female gender	0.59 (0.19, 1.89)	0.379		
Functional class (per additional class)*	0.64 (0.36, 1.17)	0.128		
Diabetes mellitus	0.47 (0.15, 1.50)	0.200		
Angiographic and procedural variables				
Multivessel disease	0.78 (0.23, 2.60)	0.680		
Lesion complexity (per additional grade)†	0.54 (0.29, 1.00)	0.051	0.69 (0.34, 1.41)	0.302
Previous PTCA	2.12 (0.89, 7.58)	0.515		
SVG lesion	0.35 (0.11, 1.14)	0.082	1.12 (0.24, 5.75)	0.834
Eccentric lesion	0.73 (0.22, 2.38)	0.837		
Ostial	4.37 (0.85, 76.9)	0.164		
Calcified lesion	0.74 (0.12, 4.49)	0.989		
Total occlusion	0.44 (0.10, 1.98)	0.544		
Thrombus	0.11 (0.03, 0.40)	0.008	0.14 (0.31, 0.67)	0.013

*Canadian Cardiovascular Society classification I to IV. †American College of Cardiology–American Heart Association classification A, B, or C (14) as modified by Ellis et al. (15). CI = confidence interval; other abbreviations as in Tables 1 and 2.

Laser thrombolysis. Although a growing clinical experience has been reported with excimer laser coronary angioplasty for complex lesions in several large multicenter registries, all reports published thus far have excluded patients with evidence of intracoronary thrombus (7–9, 25–28). There have been several reports of the effect of laser on thrombus in experimental models. LaMuraglia et al. (29) demonstrated that pulsed dye laser radiation results in efficient ablation of venous thrombus with a wide margin of safety without damage to the surrounding vascular tissue. Crea et al. (30) successfully recanalized acutely thrombosed coronary arteries in dogs. In a preliminary report (31), excimer laser angioplasty has also been shown to ablate thrombus in porcine coronary arteries.

Limitations of the study. Our study is limited by the small number of patients with intracoronary thrombus and adverse outcome. Despite this, both the clinical impression and the statistical analysis suggest that excimer laser coronary angioplasty is associated with an increased rate of major complications when intracoronary thrombus is identified. In addition, >50% of the thrombus-associated lesions were in saphenous vein grafts; however, the multivariable logistic regression analysis identified thrombus itself—not location in a saphenous vein graft—as the major predictor of poor clinical outcome.

Angiography has limited capability to identify intracoronary thrombus. Other imaging modalities may be more accurate for thrombus detection; however, preliminary work with intracoronary ultrasound suggests that distinction of thrombus from soft plaque remains a problem (32). Angioscopy has been shown to be more sensitive than angiography in the detection of intracoronary thrombus in highly selected patients with either acute myocardial infarction or unstable angina studied intraoperatively (33) or in the cardiac catheterization laboratory (34); however, we used a very rigorous definition of thrombus, derived from the work of Ambrose et al. (10), that is specific but not sensitive for the detection of intracoronary thrombus. Thus, it is unlikely that we have overestimated the incidence of intracoronary thrombus in the patients undergoing treatment with excimer laser coronary angioplasty.

Conclusions. In summary, intracoronary thrombus is the most important determinant of clinical success with excimer laser coronary angioplasty. The results with excimer laser coronary angioplasty for lesions associated with thrombus are probably similar to those reported for balloon angioplasty. The analysis presented here suggests that lesions associated with thrombus large enough to be detected angiographically should be not be treated with excimer laser coronary angioplasty. Further investigation of other strategies is needed to improve the outcome of angioplasty for this challenging problem.

Dr. Estella gratefully acknowledges the support and guidance of Professor Miguel María Iriarte.

References

1. de Feyter PJ, van den Brand M, Jaarman G, van Domburg R, Serruys PW, Suryapranata H. Acute coronary artery occlusion during and after percutaneous transluminal coronary angioplasty: frequency, prediction, clinical course, management, and follow-up. Circulation 1991;83:927–36.
2. Ellis SG, Roubin GS, King SBI, et al. Angiographic and clinical predictors of acute closure after native vessel coronary angioplasty. Circulation 1988;77:372–9.
3. Detre KM, Holmes DRJ, Holubkov R, et al. Incidence and consequences of periprocedural occlusion: the 1985–1986 National Heart, Lung, and Blood Institute Percutaneous Coronary Angioplasty Registry. Circulation 1990;82:739–50.
4. Mabin TA, Holmes DR, Smith HC, et al. Intracoronary thrombus: role in coronary occlusion complicating percutaneous transluminal coronary angioplasty. J Am Coll Cardiol 1985;5:198–202.
5. Arora RR, Platko WP, Bhadwar K, Simpfendorfer C. Role of intracoronary thrombus in acute complications during percutaneous transluminal coronary angioplasty. Cathet Cardiovasc Diagn 1989;16:226–9.
6. Myler RK, Shaw RE, Stertzer SH, et al. Lesion morphology and coronary angioplasty: current experience and analysis. J Am Coll Cardiol 1992;19:1641–52.
7. Bittl JA, Sanborn TA. Excimer laser-facilitated coronary angioplasty: Relative risk analysis of acute and follow-up results in 200 patients. Circulation 1992;86:71–80.
8. Karsch KR, Haase KK, Voelker W, Baumbach A, Mauser M, Seipel L. Percutaneous coronary excimer laser angioplasty in patients with stable and unstable angina pectoris. Acute results and incidence of restenosis during 6-month follow-up. Circulation 1990;81:1849–59.
9. Cook SL, Eigler NL, Shefer A, Goldenberg T, Forrester JS, Litvack F. Percutaneous excimer laser coronary angioplasty of lesions not ideal for balloon angioplasty. Circulation 1991;84:632–43.
10. Ambrose JA, Winters SL, Stern A, et al. Angiographic morphology and the pathogenesis of unstable angina pectoris. J Am Coll Cardiol 1985;5:609–16.
11. Detre K, Holubkov R, Kelsey S, et al. Percutaneous transluminal coronary angioplasty in 1985–1986 and 1977–1981. The National Heart, Lung, and Blood Institute Registry. N Engl J Med 1988;318:265–70.
12. Chesebro JH, Knatterud G, Roberts R, et al. Thrombolysis in Myocardial Infarction (TIMI) Trial, Phase I: a comparison between intravenous tissue plasminogen activator and intravenous streptokinase. Clinical findings through hospital discharge. Circulation 1987;76:142–54.
13. The BARI Investigators. Protocol for the Bypass Angioplasty Revascularization Investigation. Circulation 1991;84(suppl V):V–1–27.
14. Ryan TJ, Faxon DP, Gunnar RM, et al. Guidelines for percutaneous transluminal coronary angioplasty. A report of the American College of Cardiology/American Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures (Subcommittee on Percutaneous Transluminal Coronary Angioplasty). J Am Coll Cardiol 1988;12:529–45.
15. Ellis SG, Vandormael MG, Cowley MJ, et al. Coronary morphologic and clinical determinants of procedural outcome with angioplasty for multivessel coronary disease: implications for patient selection. Circulation 1990;82:1193–202.
16. Nobuyoshi M, Kimura T, Nosaka H, et al. Restenosis after successful percutaneous transluminal coronary angioplasty: serial angiographic follow-up of 229 patients. J Am Coll Cardiol 1988;12:616–23.
17. Glantz SA, Slinker BK. Regression with a qualitative dependent variable. In: Glantz SA, Slinker BK, eds. Primer of Applied Regression and Analysis of Variance. New York: McGraw-Hill, 1990:512–68.
18. Barnathan ES, Schwartz JS, Taylor L. Aspirin and dipyridamole in the prevention of acute coronary thrombosis complicating coronary angioplasty. Circulation 1987;76:125–34.
19. Laskey MA, Deutsch E, Barnathan E, Laskey WK. Influence of heparin therapy on percutaneous transluminal coronary angioplasty outcome in unstable angina pectoris. Am J Cardiol 1990;65:1425–9.
20. Grill HP, Brinker J. Nonacute thrombolytic therapy: an adjunct to coronary angioplasty in patients with large intravascular thrombi. Am Heart J 1989;118:662–7.
21. Goudreau E, DiSciascio G, Vetrovec G, et al. Intracoronary urokinase as an adjunct to percutaneous transluminal coronary angioplasty in patients

with complex coronary narrowings or angioplasty-induced complications. Am J Cardiol 1992;69:57–62.

22. Hartmann JR, McKeever LS, Stamato NJ, et al. Recanalization of chronically occluded aortocoronary saphenous vein bypass grafts by extended infusion of urokinase: initial results and short-term clinical follow-up. J Am Coll Cardiol 1991;18:1517–23.
23. Suryapranata H, de Feyter PJ, Serruys PW. Coronary angioplasty in patients with unstable angina pectoris: is there a role for thrombolysis? J Am Coll Cardiol 1988;12(suppl A):69A–77A.
24. Schieman G, Cohen BM, Kozina J, et al. Intracoronary urokinase for intracoronary thrombus accumulation complicating percutaneous transluminal coronary angioplasty for acute ischemic syndromes. Circulation 1990;82:2052–60.
25. Sanborn TA, Cumberland DC, Greenfield AC, et al. Peripheral laser assisted balloon angioplasty. Initial multicenter experience in 219 peripheral arteries. Arch Surg 1989;124:1099–103.
26. Sanborn TA, Alexopoulos D, Marmur JD, et al. Coronary excimer laser angioplasty: reduced complications and indium-111 platelet accumulation compared with thermal laser angioplasty. J Am Coll Cardiol 1990;16:502–6.
27. Litvack F, Eigler NL, Margolis JR, et al. Percutaneous excimer laser coronary angioplasty. Am J Cardiol 1990;66:1027–32.
28. Israel DH, Marmur JD, Sanborn TA. Excimer laser-facilitated balloon angioplasty of a nondilatable lesion. J Am Coll Cardiol 1991;18:1118–9.
29. LaMuraglia GM, Anderson RR, Parrish JA, Zhang DY, Prince MR. Selective laser ablation of venous thrombus: implications for a new approach in the treatment of pulmonary embolus. Lasers Surg Med 1988;8:486–93.
30. Crea F, Fenech A, Smith W, Conti CR, Abela GS. Laser recanalization of acutely thrombosed coronary arteries in live dogs: early results. J Am Coll Cardiol 1985;6:1052–6.
31. Shefer A, Forrester JS, Litvack F. Recanalization of acute thrombus: comparison of acute success and short-term patency after excimer laser coronary angioplasty, balloon angioplasty and intracoronary thrombolysis in pigs (abstr). J Am Coll Cardiol 1991;17:205A.
32. Jain A, Ramee SR, Mesa J, Collins TJ, White CJ. Intracoronary thrombus: chronic urokinase infusion and evaluation with intravascular ultrasound. Cathet Cardiovasc Diagn 1992;26:212–4.
33. Sherman CT, Litvack F, Grundfest W, et al. Coronary angioscopy in patients with unstable angina pectoris. N Engl J Med 1986;315:913–9.
34. Mizuno K, Satomura K, Miyamoto A, et al. Angioscopic evaluation of coronary artery thrombi in acute coronary syndromes. N Engl J Med 1992;326:287–91.